

UNITED STATES PATENT APPLICATION FOR:

**CONTACT RING SPIN DURING IDLE TIME AND DEPLATE
FOR DEFECT REDUCTION**

INVENTORS:

**HIRAL M. AJMERA
ROMAN M. MOSTOVOY
GLEN T. MORI**

ATTORNEY DOCKET NUMBER: AMAT/7683/CMP/ECP/RKK

CERTIFICATION OF MAILING UNDER 37 C.F.R. 1.10

I hereby certify that this New Application and the documents referred to as enclosed therein are being deposited with the United States Postal Service on APRIL 14, 2004, in an envelope marked as "Express Mail United States Postal Service", Mailing Label No. EV335470881US, addressed to: Commissioner for Patents, Mail Stop PATENT APPLICATION, P.O. Box 1450, Alexandria, VA 22313-1450

Signature



Name

Emma Koh

Date of signature

APRIL 14, 2004

CONTACT RING SPIN DURING IDLE TIME AND DEPLATE FOR DEFECT REDUCTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of United States provisional patent application serial number 60/463,972, filed April 18, 2003, which is herein incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Embodiments of the present invention generally relate to a method for preventing defects in an electrochemical plating system, and more particularly, to a method for preventing buildup of defect generating particles in an electrochemical plating bath during idle times.

Description of the Related Art

[0003] Metallization of sub-quarter micron sized features is a foundational technology for present and future generations of integrated circuit manufacturing processes. More particularly, in devices such as ultra large scale integration-type devices, *i.e.*, devices having integrated circuits with more than a million logic gates, the multilevel interconnects that lie at the heart of these devices are generally formed by filling high aspect ratio, *i.e.*, greater than about 4:1, interconnect features with a conductive material, such as copper. Conventionally, deposition techniques such as chemical vapor deposition (CVD) and physical vapor deposition (PVD) have been used to fill these interconnect features. However, as the interconnect sizes decrease and aspect ratios increase, void-free interconnect feature fill via conventional metallization techniques becomes increasingly difficult. Therefore, plating techniques, *i.e.*, electrochemical plating (ECP) and electroless plating, have emerged as promising processes for void free filling of sub-quarter micron sized high aspect ratio interconnect features in integrated circuit manufacturing processes.

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

[0004] In an ECP process, for example, sub-quarter micron sized high aspect ratio features formed into the surface of a substrate (or a layer deposited thereon) may be efficiently filled with a conductive material. ECP plating processes are generally two stage processes, wherein a seed layer is first formed over the surface features of the substrate (generally through PVD, CVD, or other deposition process in a separate tool), and then the surface features of the substrate are exposed to an electrolyte solution (in the ECP tool), while an electrical bias is applied between the seed layer and a copper anode positioned within the electrolyte solution. The electrolyte solution generally contains a source of metal that is be plated onto the surface of the substrate, and therefore, the application of the electrical bias causes the metal source to be plated onto the biased seed layer, thus depositing a layer of the ions on the substrate surface that may fill the features.

[0005] However, the decreasing size of features being filled by ECP processes in semiconductor processing requires that the plating process generate minimal defects in order to produce viable devices. Research has shown that a primary cause of plating defects is contaminants that accumulate in the plating solution over time. These contaminants may result from degraded additives, deplating particles, chemical breakdown of solution components, and other sources of contaminants known to electrochemical plating systems. Contaminants have been shown to be of particular concern after the plating bath has been idle for a period of time, *i.e.*, after the plating bath has not had an active substrate (a substrate being plated) in the plating cell for a period of time. This time period has been shown to significantly impact defects, as the contaminants in the plating solution often collect on the surface of the plating solution. When these contaminants collect on the solution surface, they then contact the surface of the next substrate to be plated when the substrate is immersed into the plating solution. The contaminants often adhere to the substrate surface and cause plating defects.

[0006] In addition to minimizing contaminant accumulation, embodiments of the invention further provide for minimization of crystallization on the electrical substrate contact pins of the contact ring. More particularly, in conventional plating

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

apparatuses, the electrical contact elements or pins of the contact ring are removed from the plating solution during idle times. As such, residue plating solution on the pins tends to dry in the ambient atmosphere and form crystals. These crystals have also been shown to cause or contribute to plating defects when the next substrate is positioned in the plating cell.

[0007] Therefore, there is a need for a method for preventing contaminants from accumulating on the surface of a plating bath and crystals from forming on the contact pins during cell idle times.

SUMMARY OF THE INVENTION

[0008] Embodiments of the invention generally provide a method for preventing accumulation of contaminants on the surface of a plating bath during idle times. Generally, the method includes immersing a portion of the contact ring of the plating head assembly into the plating solution during idle time and rotating the contact ring to circulate the plating solution and prevent the contaminants from accumulating on the surface of the solution. More particularly, the rotation of the contact ring causes the contaminants that have accumulated on the solution surface to travel over the weir and into a catch cup or basin, where they may be collected and filtered from the solution before being recirculated into the plating bath. The immersion of the contact ring further facilitates prevention of accumulation of crystals on the electrical contacts of the contact ring that result from the contact ring being out of the plating solution for any significant period of time.

[0009] Embodiments of the invention may further provide a method for removing contaminants from a plating bath contained in a weir-type plater during idle times. The method broadly includes positioning a lower portion of a substrate support assembly into the plating bath and rotating the substrate support assembly at a rotation rate of between about 1 rpm and about 60 rpm for between about 5 seconds and about 30 seconds to circulate the plating solution such that contaminants accumulating on the surface of the plating solution are urged to flow over a weir of the weir-type plater.

[0010] Embodiments of the invention may further provide a method for filtering surface contaminants from a plating solution in a weir-type plater. The method generally includes lowering an empty contact ring assembly into the plating solution, rotating the contact ring assembly to circulate an upper layer of the plating solution, receiving at least a portion of the upper layer of the plating solution over a weir, filtering the received portion of the upper layer of the plating solution to remove surface contaminants therefrom, and recirculating the filtered plating solution to the weir-type plater.

[0011] Embodiments of the invention may further provide a method for removing surface contaminants from a plating solution during idle time periods. The method generally includes positioning an empty contact ring into the plating solution, rotating the contact ring to urge the surface contaminants to flow over a weir, collecting the plating solution flowing over the weir, and filtering the collected plating solution to remove the surface contaminants therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0013] Figure 1 illustrates a top plan view of an ECP system of the invention.

[0014] Figure 2 illustrates a partial perspective and sectional view of an exemplary plating cell of the invention.

[0015] Figure 3 illustrates a perspective view of a contact ring assembly of the invention.

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

[0016] Figure 4 illustrates a sectional view of a plating cell, contact ring assembly, and head assembly of the invention.

[0017] Figure 5 illustrates a sectional view of a plating cell, contact ring assembly, and head assembly of the invention during a plating solution circulation method of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] The present invention is generally directed to a method for circulating a plating bath during idle times in order to prevent contaminants from collecting on the surface of the plating bath, which may then contact a substrate surface during immersion into the bath and cause defects in the subsequently plated surface. The method includes using the contact ring of the plating apparatus to circulate the plating solution via insertion of the contact ring into the plating solution during idle times and rotating the contact ring.

[0019] Figure 1 illustrates a top plan view of an ECP system 100 of the invention. ECP system 100 includes a factory interface (FI) 130, which is also generally termed a substrate loading station. Factory interface 130 includes a plurality of substrate loading stations configured to interface with substrate containing cassettes 134. A robot 132 is positioned in factory interface 130 and is configured to access substrates contained in the cassettes 134. Further, robot 132 also extends into a link tunnel 115 that connects factory interface 130 to processing mainframe or platform 113. The position of robot 132 allows the robot to access substrate cassettes 134 to retrieve substrates therefrom and then deliver the substrates to one of the processing cells 114, 116 positioned on the mainframe 113, or alternatively, to the annealing station 135. Similarly, robot 132 may be used to retrieve substrates from the processing cells 114, 116 or the annealing chamber 135 after a substrate processing sequence is complete. In this situation robot 132 may deliver the substrate back to one of the cassettes 134 for removal from system 100.

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

[0020] The anneal chamber 135 generally includes a two position annealing chamber, wherein a cooling plate/position 136 and a heating plate/position 137 are positioned adjacently with a substrate transfer robot 140 positioned proximate thereto, e.g., between the two stations. The robot 140 is generally configured to move substrates between the respective heating 137 and cooling plates 136. Further, although the anneal chamber 135 is illustrated as being positioned such that it is accessed from the link tunnel 115, embodiments of the invention are not limited to any particular configuration or placement. As such, the anneal chamber may be positioned in communication with the mainframe 113.

[0021] As mentioned above, ECP system 100 also includes a processing mainframe 113 having a substrate transfer robot 120 centrally positioned thereon. Robot 120 generally includes one or more arms/blades 122, 124 configured to support and transfer substrates thereon. Additionally, the robot 120 and the accompanying blades 122, 124 are generally configured to extend, rotate, and vertically move so that the robot 120 may insert and remove substrates to and from a plurality of processing cells 102, 104, 106, 108, 110, 112, 114, 116 positioned on the mainframe 113. Similarly, factory interface robot 132 also includes the ability to rotate, extend, and vertically move its substrate support blade, while also allowing for linear travel along the robot track that extends from the factory interface 130 to the mainframe 113. Generally, process cells 102, 104, 106, 108, 110, 112, 114, 116 may be any number of processing cells utilized in an electrochemical plating platform. More particularly, the process cells may be configured as electrochemical plating cells, rinsing cells, bevel clean cells, spin rinse dry cells, substrate surface cleaning cells, electroless plating cells, metrology inspection stations, and/or other processing cells that may be beneficially used in conjunction with a plating platform. Each of the respective processing cells and robots are generally in communication with a process controller 111, which may be a microprocessor-based control system configured to receive inputs from both a user and/or various sensors positioned on the system 100 and appropriately control the operation of system 100 in accordance with the inputs.

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

[0022] In the exemplary plating system illustrated in Figure 1, the processing cells may be configured as follows. Processing cells 114 and 116 may be configured as an interface between the wet processing stations on the mainframe 113 and the dry processing regions in the link tunnel 115, annealing chamber 135, and the factory interface 130. The processing cells located at the interface locations may be spin rinse dry cells and/or substrate cleaning cells. More particularly, each of cells 114 and 116 may include both a spin rinse dry cell and a substrate cleaning cell in a stacked configuration. Processing cells 102, 104, 110, and 112 may be configured as plating cells, either electrochemical plating cells or electroless plating cells, for example. Processing cells 106, 108 may be configured as substrate bevel cleaning cells. Additional configurations and implementations of an electrochemical processing system are illustrated in commonly assigned United States Patent Application Serial No. 10/435,121 filed on December 19, 2002 entitled "Multi-Chemistry Electrochemical Processing System", which is incorporated herein by reference in its entirety.

[0023] Figure 2 illustrates a partial perspective and sectional view of an exemplary plating cell 200 that may be implemented in processing cell locations 102, 104, 110, and 112. The electrochemical plating cell 200 generally includes an outer basin 201 and an inner basin 202 positioned within outer basin 201. Inner basin 202 is generally configured to contain a plating solution that is used to plate a metal, e.g., copper, onto a substrate during an electrochemical plating process. During the plating process, the plating solution is generally continuously supplied to inner basin, and therefore, the plating solution continually overflows the uppermost point (generally termed a "weir") of inner basin 202 and is collected by outer basin 201 and drained therefrom for chemical management and recirculation. Plating cell 200 is generally positioned at a tilt angle, i.e., the frame portion 203 of plating cell 200 is generally elevated on one side such that the components of plating cell 200 are tilted between about 3° and about 30°, or generally between about 4° and about 10° for optimal results. The frame member 203 of plating cell 200 supports an annular base member on an upper portion thereof. Since frame member 203 is elevated on one side, the upper surface of base member 204 is generally tilted from

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

the horizontal at an angle that corresponds to the angle of frame member 203 relative to a horizontal position. Base member 204 includes an annular or disk shaped recess formed into a central portion thereof, the annular recess being configured to receive a disk shaped anode member 205. Base member 204 further includes a plurality of fluid inlets/drains 209 extending from a lower surface thereof. Each of the fluid inlets/drains 209 are generally configured to individually supply or drain a fluid to or from either the anode compartment or the cathode compartment of plating cell 200. Anode member 205 generally includes a plurality of slots 207 formed therethrough, wherein the slots 207 are generally positioned in parallel orientation with each other across the surface of the anode 205. The parallel orientation allows for dense fluids generated at the anode surface to flow downwardly across the anode surface and into one of the slots 207. Plating cell 200 further includes a membrane support assembly 206. Membrane support assembly 206 is generally secured at an outer periphery thereof to base member 204, and includes an interior region configured to allow fluids to pass therethrough. A membrane 208 is stretched across the support 206 and operates to fluidly separate a catholyte chamber and anolyte chamber portions of the plating cell. The membrane support assembly may include an o-ring type seal positioned near a perimeter of the membrane, wherein the seal is configured to prevent fluids from traveling from one side of the membrane secured on the membrane support 206 to the other side of the membrane. A diffusion plate 210, which is generally a porous ceramic disk member is configured to generate a substantially laminar flow or even flow of fluid in the direction of the substrate being plated, is positioned in the cell between membrane 208 and the substrate being plated. The exemplary plating cell is further illustrated in commonly assigned United States Patent Application Serial No. 10/268,284, which was filed on October 9, 2002 under the title "Electrochemical Processing Cell", claiming priority to United States Provisional Application Serial No. 60/398,345, which was filed on July 24, 2002, both of which are incorporated herein by reference in their entireties.

[0024] Figure 3 illustrates an exemplary contact ring and thrust plate assembly 310 of the invention. The contact ring and thrust plate assembly 310 generally

includes a mounting member 312 attached to the contact ring 350 via attachment members 316. The attachment members 316 may be spaced sufficiently to allow insertion of the substrate (*i.e.*, a spacing of the attachment members 316 may be greater than a diameter of the substrate). The mounting member 312 may be used to attach or connect the contact ring 350 to a head assembly (not shown) that is configured to vertically actuate, rotate, and tilt the contact ring 350. The mounting member 312, contact ring 350, and the attachment members 316 may each be coated with a plating-resistant material, such as a PTFE material (*e.g.*, Aflon® or Tefzel®) or any other suitable plating-resistant coating material. The contact ring 350 generally includes a substrate seating surface 352 that is adapted to receive the substrate with the plating surface of the substrate facing the plating bath, which is generally positioned below ring 350. The assembly 310 also includes a thrust plate 344 with an attached seal plate 342 that is adapted to be vertically actuated (toward the contact ring 350) so that a securing force may be exerted on the backside substrate such that the substrate plating surface is pushed against the seating surface 352 of ring 350 for processing. The securing force applied by the thrust plate 344 may be sufficient to ensure adequate sealing between an annular sealing member 348 disposed on the seal plate 342 and the non-plating surface (backside) of the substrate. The annular sealing member 348, which may be an o-ring type seal, for example, may be adapted to contact the non-plating surface (backside) of the substrate at a substantially equal location radially inward from an edge of the substrate as the contacts 354 engage the plating surface of the substrate.

[0025] The securing force exerted by the thrust plate 344 may also be sufficient to ensure adequate electrical contact between the plating surface (generally an electrically conductive seed or barrier layer) of the substrate and the contacts 354 extending from the substrate seating surface 352 of the contact ring 350. The contacts 354 are generally adapted to electrically contact the plating surface of the substrate in order to supply an electrical plating bias to the plating surface during the plating process. The contacts 354 may be made of any suitable conductive material, such as copper (Cu), platinum (Pt), tantalum (Ta), titanium (Ti), gold (Au),

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

silver (Ag), stainless steel, an alloy thereof, or any other suitable conducting material.

[0026] As illustrated in Figure 3, the electrical substrate contacts 354 may be formed above downwardly extending scallops 356 positioned on a lower surface of the contact ring 350 in a generally circular pattern. The contacts 354 may vary in number, for example, according to a size of the substrate. The contacts 354 may also be flexible to contact non-plating surfaces with non-uniform heights. Electrical power may be supplied to the contacts 354 via a power supply (not shown). The power supply may supply and control electrical power to all of the electrical contacts 354 cooperatively, banks or groups of the electrical contacts 354 separately, or to the individual contacts 354. In embodiments where current is supplied to groups or individual contacts 354, a current control system may be employed to control the current applied to each group or pin. An exemplary current control system may be found in commonly assigned U.S. Patent No. 6,432,282, which is incorporated herein in its entirety.

[0027] For some embodiments, the contact ring 350, attachment members 316, and mounting member 312 may all be made of an electrically conductive material. As with the contacts 354, the contact ring 350, attachment members 316, and mounting member 312 may be made of any suitable electrically conductive material and, for some embodiments, may be made of stainless steel. Accordingly, the attachment members 316 may electrically couple the mounting member 312 and the contact ring 350. Therefore, power may be supplied to the contacts 354 by one or more electrical connections between the mounting member 312 and a power supply.

[0028] Further, for some embodiments, the mounting member 312 may be physically and electrically coupled with the thrust plate mounting plate 346, which may also be made of an electrically conductive material and may be attached to a power supply. The mounting member 312 or mounting plate 346 may be connected to the power supply via any suitable attachment means adapted to provide power to

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

the contacts 354 as the substrate securing assembly 310 is moved (*i.e.*, raised, lowered and rotated) by the head assembly, which will be further discussed herein.

[0029] As previously described, the seal plate 342 may be attached to the thrust plate 344. The thrust plate 344 may be adapted to move (*i.e.*, up and down) independently of the contact ring 350 to exert a securing force with the sealing member 348 on the non-plating surface of a substrate to secure the substrate to the substrate seating surface 352 of the contact ring 350. The sealing member 348 may be designed to provide a uniform contact force between the contacts 354 and the plating surface of the substrate.

[0030] For example, the sealing member 348 may be made of a pliable material designed to decrease an effective spring constant of the sealing member 348. In other words, the sealing member 348 may compress to adapt to slight non-uniformities in the non-plating surface of the substrate (or slight non-uniformities in the annular sealing member 348). For example, as the sealing member 348 compresses, less force may be needed to seal against the highest point of the non-plating surface before sealing against the lowest point. With less force difference between the highest and lowest points, the local force on the non-plating surface of the substrate, and therefore on the contacts 354 in contact with the plating surface of the substrate, may be more uniform. A more uniform force on the contacts 354 may lead to uniform contact resistance and improved plating uniformity.

[0031] The plurality of scallops 356 may be formed on a bottom surface of the contact ring 350 below the plurality of contacts 354. The size and shape of the scallops 356 are not limited and may vary according application. For example, as illustrated in FIG. 2, the scallops 356 formed below the contacts 354 may be substantially rectangular in shape. For other embodiments, however, scallops may be other shapes, including, but not limited to rounded shapes (*e.g.*, semi-cylindrical or hemispherical) and triangular shapes (*e.g.*, pyramid or saw-tooth shaped), etc. As illustrated, the scallops 356 may extend from a bottom surface of the contact ring 350 (*e.g.*, opposite the substrate seating surface 352). However, for other

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

embodiments, scallops may extend from the substrate seating surface 352, in effect raising the contacts 354. A description of the structure and function of the scallops may be found in commonly assigned U.S. Patent Application Serial No. 10/278,527, filed on October 22, 2002, which is incorporated by reference herein.

[0032] Figure 4 illustrates an assembled plating cell 200, contact ring assembly 310, and a head assembly 400. The cell 200, contact ring 310, and the head assembly 400 cooperatively operate to receive a substrate, immerse the substrate in the plating solution contained in the plating cell 200, plate the substrate, and remove the substrate from the plating solution. The head assembly 400 is generally configured to impart motion to the contact ring assembly 310. More particularly, the head assembly is configured to rotate the contact ring assembly 310, vertically actuate the contact ring assembly 310, and pivot the contact ring assembly 310 about a pivot point 402 that is generally near the vertical axis of the head assembly. This pivotal movement allows the contact ring (and the substrate positioned thereon) to be tilted such that the substrate surface is not horizontal. The head assembly 400 is configured to rotate, pivot, and vertically actuate the contact ring assembly 310 all at the same time, or alternatively, the head assembly 400 conduct rotation, vertical actuation, and/or tilting motions in any combination, or alone if desired.

[0033] As noted above, during idle times, *i.e.*, during time periods when substrates are not being plated in plating cell 200, contaminants have a tendency to accumulate or collect on the upper surface of the plating solution contained within plating cell 200. More particularly, during plating operations, the contact ring assembly 310 having a substrate secured therein is lowered into the upper portion of the plating solution. The contact ring assembly 310 is generally rotated during the plating process, and therefore, the contact ring assembly 310 operates to circulate of the plating solution within plating cell 200. However, during idle times, the contact ring assembly 300 is conventionally removed from plating solution, and therefore, the contact ring assembly 310 no longer facilitates circulation of the plating solution within plating cell 200. As such, contaminants in the plating solution are allowed to accumulate or collect on the plating solution surface.

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

[0034] Further, as noted above, removal of the contact ring from the plating solution leaves a residue of the plating solution on the ring. This plating solution tends to dry when exposed to the ambient atmosphere, and this drying has been shown to form crystals on the contact ring, and in particular, the contact pins. These crystals have been shown to cause plating defects in subsequently plating substrates.

[0035] Embodiments of the invention generally provide a method for preventing the accumulation of contaminants on the surface of the plating solution during idle times, as well as a method for minimizing crystal formation on the contact ring. More particularly, embodiments of the invention provide for a method for circulating the plating solution in the plating cell during idle times, such that contaminants accumulating all this surface of the plating solution may be urged over the weir of the plating cell and circulated through a filtration system, were these contaminants may be removed from the plating solution.

[0036] In order to circulate the plating solution, and more particularly, in order to circulate or agitate the plating solution near the surface of the plating solution where contaminants tend to accumulate, the contact ring assembly ring 310 may be moved into the plating solution and used to circulate the plating solution near the surface thereof. More particularly, as illustrated in Figure 5, contact ring assembly 310 may be lowered into the plating solution and rotated in order to circulate the plating solution near the surface thereof. Generally, the contact ring assembly 310 will not be fully immersed in the plating solution during this process. Rather, the lower portion of the contact ring assembly 310, *i.e.*, contact ring member 350 and scallops 356 may be lowered into the plating solution and rotated so that the upper surface of the plating solution may be circulated.

[0037] Alternatively, the contact ring assembly 310 may be lowered such that only scallops 356 are immersed in the plating solution and used to circulate the upper surface thereof. This embodiment may have particular advantages where it is desirable to prevent the plating solution from contacting the electrical contact

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

members 354 during idle times, as immersion of only scallop portions 356 generally will not cause the plating solution to contact the electrical contact members 354.

[0038] The process or method of circulating the upper surface of the plating bath contained within plating cell 200 during idle times generally includes immersing at least a lower portion of the contact ring assembly 310 into the plating solution, and rotating the contact ring assembly with 310 at a sufficient rotation rate to circulate or agitate the upper surface of the plating solution. The contact ring assembly 310 is generally rotated at a rate of between about 1 rpm and about 100 rpm during the idle time circulation of the plating solution in order to circulate or agitate the solution enough to urge contaminants to flow over the weir 202. More particularly, the contact ring assembly may be rotated in the plating solution at a rotation rate of between about 10 rpm and about 30 rpm during idle times to circulate the upper surface of the plating solution.

[0039] Circulation of the upper surface of the plating solution within the plating cell 200 causes contaminants to flow over weir 202 and be captured in outer basin 201. Once the contaminants are captured in outer basin 201, they may be drained therefrom and circulated through the plating solution recirculation system. The plating solution recirculation system generally includes one or more filters configured to separate the contaminants in the plating solution from being the desired constituents. For example, a porous fiber-type filter and having a pores size of between about 0.05 microns and about 2.5 microns may be used to filter the contaminants from the plating solution. More particularly, the pore size of the filter may be between about 0.1 micron and about 0.2 microns.

[0040] In another embodiment of the invention, insertion and rotation of the contact ring in the plating solution during idle times may be used to facilitate contact ring deplating processes. More particularly, contact ring deplating processes (the process of immersing the contact ring in the plating solution without a substrate thereon and reversing the plating bias to deplate any copper that has accumulated on the electrical contact pins 354 therefrom) operate to shed copper particles from

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

the contact pins into the plating solution. Further, these copper particles may be of sufficient size such that they are not easily dissolved into the plating solution. In this situation with the insertion and rotation of the contact ring into the plating solution during contact pins deplating operations may be used to facilitate removal of unwanted contaminants, *i.e.*, the large copper particles generated by the deplating process. The insertion and rotation of the contact ring during the plating operations serves two purposes. First, insertion and rotation circulates the upper surface of the plating solution, and therefore, operates to urge copper particles generated by the deplating process over the weir 202, where these large copper particles may again be collected by the filters of the plating system. Second, insertion and rotation of the contact ring circulates the plating solution during the deplating process, and therefore, facilitates dissolving of the smaller copper particles back into the plating solution.

[0041] As noted above, the process of plating a conductive material, such as copper, onto a substrate via an ECP process generally includes electrically contacting the plating surface of the substrate. Additionally, often times the electrical contact between the plating apparatus and the plating surface is exposed to the plating solution. As such, the exposed surfaces of the conductive electrical contact elements (354 in the illustrated embodiment of the invention) are also subject to the plating process, *i.e.*, the plating material accumulates on the contact elements. This is known to cause variances in the plating process and to increase the defect ratios, and as such, it is desirable to remove the accumulation from the contact elements via a deplating process.

[0042] The process of deplating contact pins 354 may include immersing the contact ring 350 into the plating solution such that the contact pins 354 are immersed in the plating solution. The contact ring may be rotated at between about 1 rpm and about 100 rpm, or more particularly, between about 10 rpm and about 30 rpm. An electrical deplating bias (anodic current) may be applied to the contact pins during the rotation, wherein the deplating bias has a voltage of between about 100 mv and about 10 volts. The deplating bias may be a constant bias, or alternatively,

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

the deplating bias may be stepped, ramped, periodically reversed, or otherwise varied from a constant voltage as desired to facilitate deplating of the contact pins. The deplating bias may be applied for a duration of between about 1 second and about 30 seconds, for example. Once the deplating bias duration has expired, the bias may be terminated and the contact ring may be removed from the solution. Alternatively, if the plating system is still in an idle mode, then the deplating bias may be terminated and the contact ring may remain immersed in the plating solution and may continue to be rotated, such that surface contaminants may continue to be removed from the solution.

[0043] However, conventional deplating processes have encountered several challenges to effectively deplating. More particularly, the deplating rate obtained by applying a fixed cell-voltage for a fixed duration is in fact uncontrolled and can vary widely over the course of the deplating step. This can cause undesirable physical and chemical processes to occur when the deplating rate is either high, low, or too long. Such effects may include breakdown of certain chemical components in the bath or generation of unwanted byproducts. Additionally, deplating for a specified amount of time provides no guarantee that the residue has been entirely removed from the contacts, and insufficient deplating can lead to accumulation of residue from work-piece to work-piece and variations in plating performance. Using a pre-specified deplating time is particularly problematic if there are statistical variations in the degree of residue left after each work-piece is complete, or if there are variations between work-pieces due to differences in substrate types or plating recipes.

[0044] Embodiments of the invention address these concerns with a novel control scheme for a contact pin deplating process. More particularly, after removal of a completed work-piece from the plating cell, the electrical contact pins 354 are re-immersed in the plating solution. A constant electrical current is applied to the contacts to remove the metallic residue electrochemically. The constant current ensures a constant rate of deplating so that undesired processes can be excluded, most notably oxygen evolution and/or oxidation of essential constituents in the plating bath. Throughout this step, the cell voltage is monitored by suitable electrical

instrumentation. When the metallic residue has been removed from the contact pins 354, the cell voltage will exhibit a sharp change (increase) that signals the endpoint of deplating step, *i.e.*, indicates that all of the copper has been removed from the contact pins 354. Appropriate control software and hardware may be used to detect the value or rate of change of the cell voltage and respond by turning off the deplating current. Once this endpoint has been reached, the deplating step may be deemed complete and the contacts are ready for the next work-piece. Alternatively, one or more additional deplating steps under current or voltage control may also be applied to remove any trace residue from the contacts or to further condition the contacts.

[0045] While the embodiment described above involves the use of a constant controlled-current deplating step optionally followed by additional steps, any combination of one or more steps under current and/or voltage control may be used in alternative embodiments. In all of these cases, one of the key aspects of this invention is the use of real-time electrical measurements on the cell to signal the endpoint of deplating instead of a pre-specified deplating time. For example, any of the deplating steps (including the first step) may be run under voltage control and the cell current may be monitored using suitable instrumentation and used to signal the endpoint of deplating. Voltage control is generally defined as applying a constant total voltage to the cell or a constant voltage to the contacts relative to a reference electrode immersed in the deplating bath. In these cases, the current will fall to a very low value and change very slowly once the contacts are clean. The value or rate of change of the current in the cell can be used to trigger the end of the deplating step.

[0046] In another embodiment of this invention, deplating may be performed with a sequence of steps at different current or voltage values or with a smoothly varying current or voltage applied to the cell or the contacts. In this manner, any desired variation of the voltage of the contacts and/or the deplating rate can be applied in order to achieve satisfactory conditioning of the contacts while minimizing undesired chemical and physical processes.

PATENT

Attorney Docket No.: AMAT/7683/CMP/ECP/RKK

Express Mail No.: EV335470881US

[0047] In another embodiment of the invention, the immersion of the contact ring 350 into the plating solution during idle times may be used to minimize crystal formation on the contact pins 354. More particularly, it has been shown that when electrical contact assemblies are removed from plating solutions, the residual plating solution that adheres to the contact assemblies, and in particular, the electrical contact pins 354, tends to dry on the contact pins 354 and form crystalline growths thereon. These crystalline growths are then reintroduced into the plating solution when the contact assembly is immersed in a subsequent plating process. However, once the crystals are formed, they generally become contaminants in the plating solution that are capable of causing defects in the plated layers. Therefore, embodiments of the invention are configured to minimize and/or eliminate the formation of these crystals. The process of minimizing and/or eliminating the formation of the crystals includes immersing the electrical contact assembly into the plating solution during idle times so that the plating solution does not have a chance to crystallize on the assembly components.

[0048] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, wherein the scope thereof is determined by the following claims.